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PRODUCTION ENGINEERING MEASURE FOR TYPE 7890 SUPER POWER HYDROGEN THYRATRON

CONTRACT NO. DA-36-039-SC-85984
ORDER NO. 19034-PP-62-81-81

PLACED BY: Industrial Preparedness Directorate
U. S. Army Electronics Materiel Agency
225 South Eighteenth Street
Philadelphia 3, Pennsylvania

CONTRACTOR: TUNG-SOL ELECTRIC INC.
CHATHAM ELECTRONICS DIVISION
LIVINGSTON, NEW JERSEY

PRODUCTION ENGINEERING MEASURE FOR

TYPE 7890 SUPER POWER HYDROGEN THYRATRON

Report No. 4
Fourth Quarterly Progress Report

Period
8 December 1962 to 7 March 1963

Objective: Establishment and demonstration of the capability to produce the type 7890 hydrogen thyratron.

Contract No. DA-36-039-SC-85984

Technical Requirements: Signal Corps Technical Requirements SCL-7001/59 dated 3 October 1960. Entitled: Tube, Electron, Phase I Super Power Hydrogen Thyratron.

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Approved By: B J Steiger

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ABSTRACT

A summary of expected difficulties and difficulties actually encountered constructing the first tube is given. The principal structural difficulty, the cracking of anode cups, has been eliminated by addition of another part to the anode subassembly. The support of the gradient grid structure is presently unsatisfactory and requires further investigation. The jigs and fixtures for some of the brazing operations require modification.

The first tube performed within specifications on the Operation (2) tests with the exception that the grid drive to start operation was higher than desired. The high current required in Operation (1) tests produced oscillations on the leading edge of the current pulse and excessive dissipation in the grids. The indicated changes for the next tube are discussed.

PURPOSE

The object of this contract is the demonstration of capability to produce the type 7890 Super Power Hydrogen Thyratron according to the Signal Corps Technical Requirements SCL-7001/59 dated 3 October 1960. To this end, the contract requires delivery of tubes and reports representing the state of the program at various stages.

The capability to produce ten tubes per month on a single shift basis is to be proven by a pilot production run.

A final report covering the completion of the Measure and a Bill of Materials and Parts are to be submitted.

Reports required by Step II of Signal Corps Industrial Preparedness Procurement Requirements No. 15 are to be prepared and submitted.

NARRATIVE AND DATA

I. Progress Toward Tube Production

The type 7890 hydrogen thyratron as constructed in the particular design with which this contract is concerned divides into four major subassemblies, three of which combine to form the tube envelope. Several problems were anticipated in connection with each of the subassemblies and other problems not foreseen have arisen. In general, the latter have been few but troublesome. Data from the first 7890 in operation have indicated certain changes that are either required or are desirable.

A. Anode Subassembly

The principal difficulty expected in the fabrication of the anode subassembly was warping of the anode face so that it would not be perfectly flat. This warping was minimized by using a single 0.060 inch thick disc of molybdenum for the anode face and supporting it at its edges as illustrated in Figure 1. The warping was still present to a small but tolerable degree. The principal anode problem was unexpected: the anode cups cracked when brazed to the ceramic envelope. This cracking occurred with Kovar, Rodar, and Ceramvar materials whether or not they were copper clad. This problem was discussed in the last report and the solution proposed

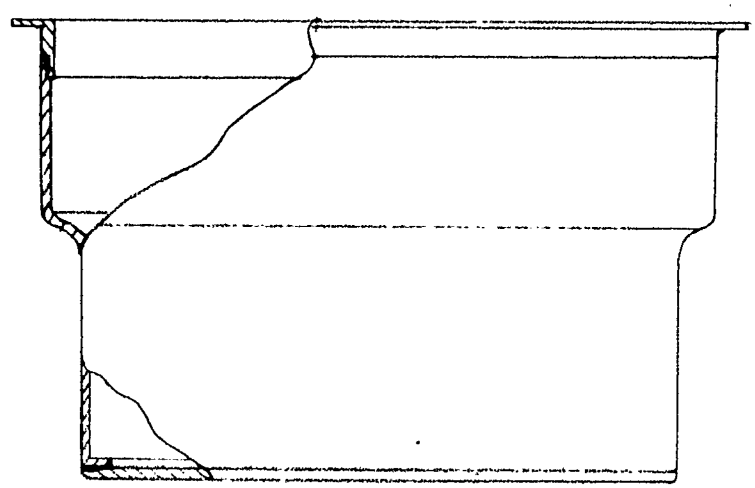


FIGURE 1

ANODE CUP MODIFIED WITH ADDITIONAL FLANGE

at that time has been satisfactory although it introduces more complications in the tube assembly.

This solution consisted of separating the sealing flange from the anode cup and making it a separate part which had not been subjected to the working stresses set up in the metal when the cups were formed. The flange is brazed to the cup, Figure 1, with a brazing filler that flows at a temperature intermediate to those required to braze the molybdenum anode face and to braze the metal subassemblies to the ceramic cylinders to form the tube envelope.

The addition of this step has complicated the machining of the parts and has caused certain other effects. A higher temperature braze filler is now required for the first assembly step so that the sequential brazes can be made with materials whose plastic ranges do not overlap. The higher temperature braze produces somewhat more warpage in the anode face than was previously present. This warping apparently was acceptable in the first operating tube but it may require corrective measures in the future.

B. Gradient Grid Subassembly

The gradient grid structure in the 7890 must absorb and dissipate considerable energy in certain conditions of operation. The principal problem expected with this subassembly was the

support of the grid partition and cylinders inside the external grid ring. The supporting structure is responsible for the dimensional stability of the grid and must conduct a major portion of the heat away from the grid. The external grid ring conducts this heat to the surrounding medium, usually air.

The original design of the tube published in Report No. 1 illustrated a single spider of copper supporting the grid from the external grid ring. Later thoughts on the subject reasoned that a double spider, Figure 2, would provide better heat flow and balanced expansion forces. The first tube was assembled using the double spider but the assembly problems appear too difficult for practical application. The placement of the braze filler material is very difficult in this design and the fingers of the spiders do not all braze uniformly to the external ring. The brazing problem can possibly be eased by improved jigs but the assembly operation leaves many things to be desired.

The brazing of the grid cylinders to the partition has produced a problem which may require some redesign to overcome if it proves critical. If the grid cylinders are not perfectly circular they tend to move out of the grooves in the grid partition during brazing; this produces an assembly which does not have its axis perpendicular to the partition and produces interelectrode spacings that are too close to the anode or control grid at the open ends of

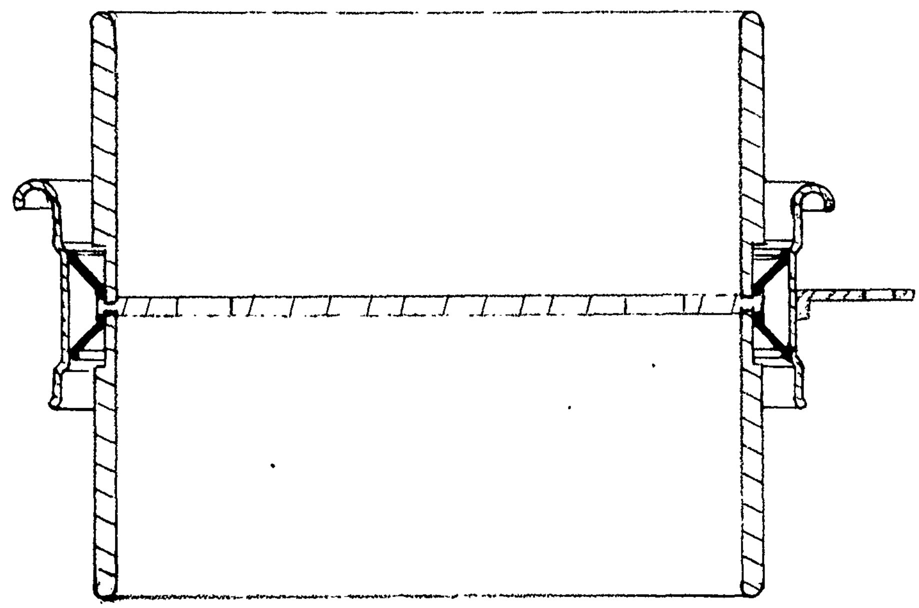


FIGURE 2

GRADIENT GRID SUPPORTED FROM EXTERNAL
GRID RING BY A DOUBLE SPIDER

This arrangement is too complicated to be practical;
the assembly for brazing is very difficult.

the gradient grid structure. This can be overcome by making the subassembly in two steps, the assembly of the cylinders and the partition being made in one step and the assembly to the outer ring in another step. The gradient grid in the first tube was not perfectly aligned and the performance of the tube is probably influenced by the misalignment.

C. Control Grid Subassembly

The control grid subassembly, Figure 3, consists of an external grid ring like that used for the gradient grid, a grid cylinder, grid partition, and grid baffle. No real problems were anticipated with the assembly. It was considered likely that there would be dimensional changes required for the baffle opening or the grid slots since these are the result of compromise between the requirements of different operating conditions.

The grid used in the first tube maintained a satisfactory degree of flatness at the partition. It was not a good coaxial assembly and certain tooling changes will be made. A second grid was assembled for the next tube and it too shifted in the jig so that its axis is not coincident with that of the external ring.

D. The Envelope

The anode, gradient grid, control grid, a cathode sealing

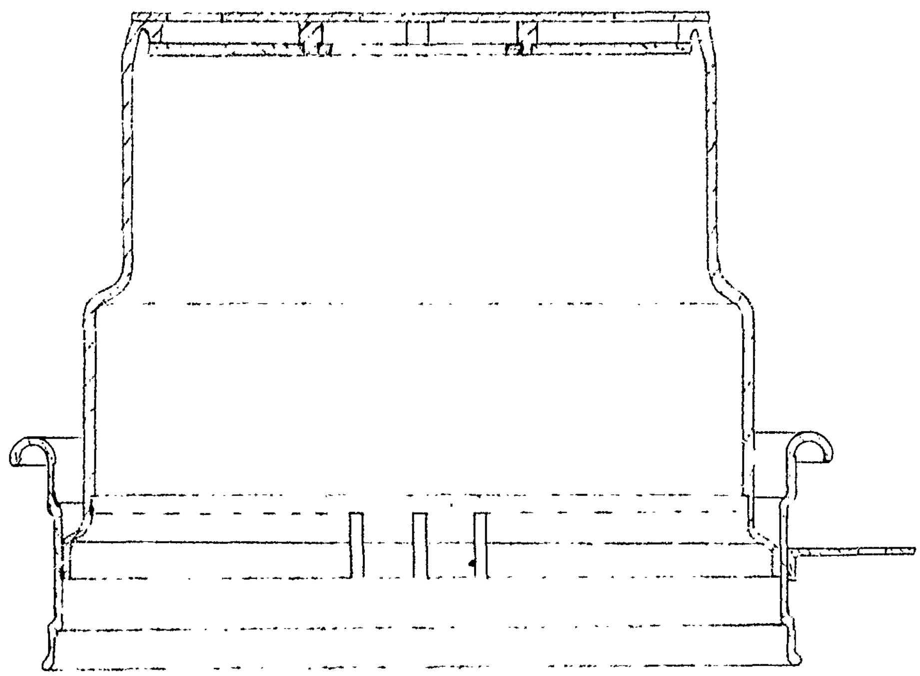


FIGURE 3

CONTROL GRID SUBASSEMBLY

ring, and four ceramic cylinders are assembled together by brazing to form the tube envelope. The assembly includes two butt brazes and five compression brazes. The principal problems expected were occasional vacuum leaks. The likelihood of a leak is increased by any out-of-roundness of an external grid ring or cathode seal ring so that the flow of braze filler into the joint is uneven. There were several leaks in early trial tubes. There was no leak in the first 7890 envelope. Such leaks can usually be repaired by a rebrazing operation.

E. The Cathode-Reservoir Subassembly

The cathode-reservoir subassembly consists of three major sections: the cathode with its heaters and heat shields, the reservoir assembly, and the cathode header which supports the remainder of the subassembly and provides closure of the envelope.

The cathode surface used in the first tube is of conventional corrugated cylindrical form of approximately 150 square centimeters area. No problems were anticipated in supplying the required current from this cathode surface. The heater power of 130 watts heats the surface to emitting temperature but changes in the power input and heat shielding may be made later to increase the heating rate. The baffling of the cathode was recognized to be a problem because of the short space available between the top of the

emitter and the grid baffle. Results from the first tests indicate the present baffling is too tight for easy firing.

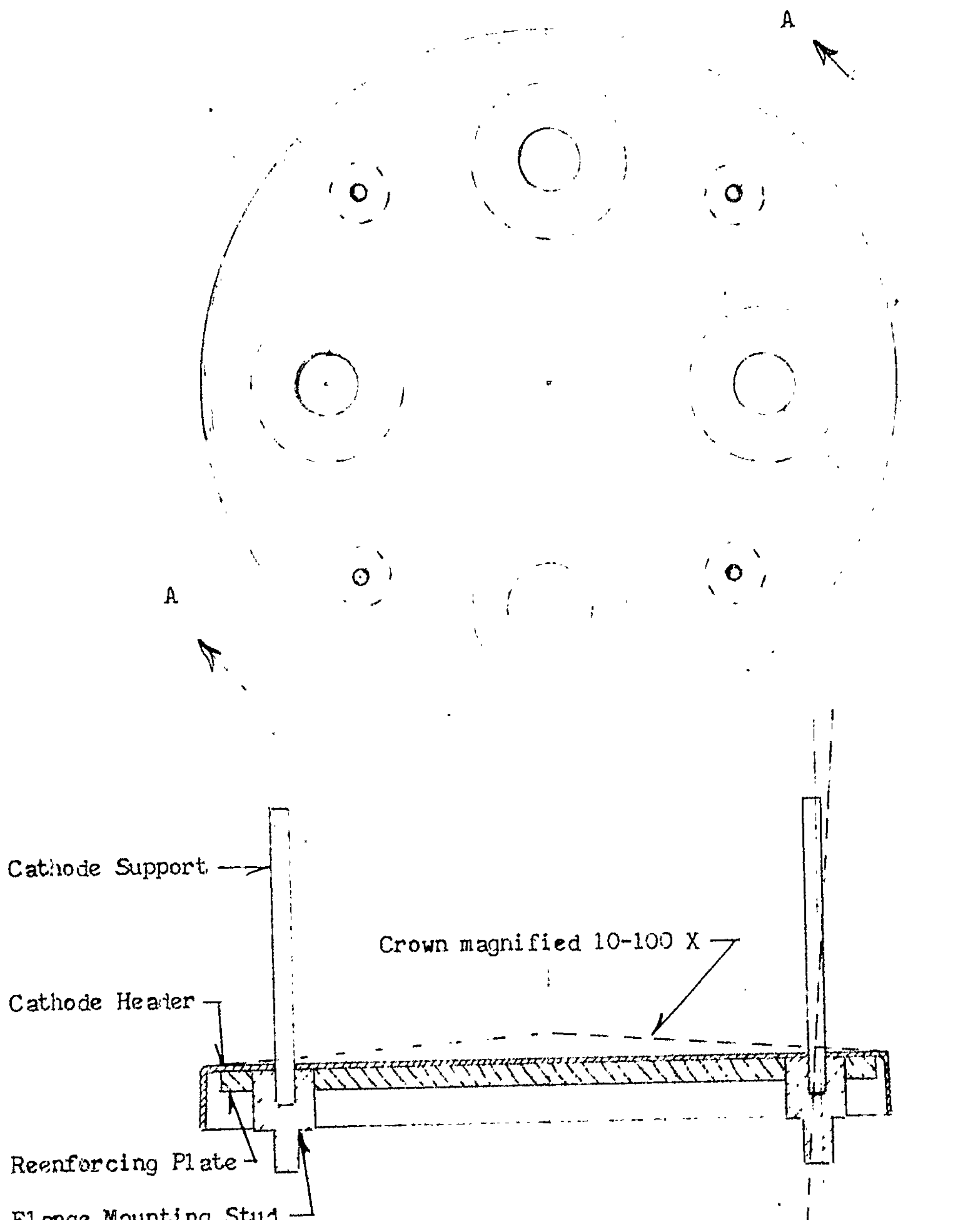
The Signal Corps Technical Requirements SCL-7001/59 listing the electrical specifications for the type 7890 requires that the reservoir current be between 8.0 and 12.0 amperes when the reservoir voltage is 3.5 volts and the cathode heater voltage is 6.3 volts. This requirement stems from the type of reservoir used in the original version of the tube. This was a multiple unit hydride type reservoir which was well proven at the time the tube was first proposed. In the intervening years, reservoir technology has improved* and the more efficient metallic reservoir has to a large extent displaced the hydride type. Several later versions of the hydride reservoir are also improved and have reduced operating power requirements.

The metallic reservoir used in this version of the 7890 is made of two units each consisting of a tube of titanium metal heated by a coaxial tungsten heater. With the proper gas loading, at 3.5 volts across the heater the current requirement per unit is only 3.33 amperes or 6.66 amperes, total. In order to increase the

* See pages 42 - 45, Final Report Covering Phase II, Signal Corps Contract Number DA-36-039-SC-64621, Department of the Army Project Number 3-19-02-032, Signal Corps Project Number 313B, Research Study and Development of Clipper Tube, Gas Filled, Chatham Electronics Division, Tung-Sol Electric, Inc., John J. McArtney, October 1, 1956 to November 14, 1957.

current to meet the minimum current limit of the tube specification, an additional heater coil was placed external to the reservoir structure but electrically in parallel with the reservoir heaters. In the first tube this heater was unshielded and placed perpendicular to the axes of the reservoir cylinders and parallel to the cathode header. In this position its influence on the temperature of the titanium metal cylinders is a minimum. The reservoir is shielded from the cathode by an open sided metal box fastened to the cathode header. Several tests will be required to determine the amount of thermal isolation necessary or desired between cathode and reservoir.

The cathode header contains the bushings carrying the cathode and reservoir heater currents into the tube. Because of its area and flat surface, a reinforcing plate is brazed to the header to prevent collapse during the tube exhaust. Figure 4 shows that because of unbalanced expansion forces there is a small crown on the header; this crown seems dependent on the manufacturing method used for the header. Several headers have been made in different brazing furnaces and of different materials so far as the reinforcing plate is concerned and the amount of distortion seems more dependent on the method of manufacture than on materials.



Section through cathode header sub-assembly showing effect of crown on verticals to header surface

FIGURE 4

CATHODE HEADER SUBASSEMBLY

Headers made in pusher type furnaces distort proportional to their rate of cooling. Headers made in a retort furnace show negligible distortion. This is important to the extent that it will cause further loading on the retort furnace facilities if it is necessary to eliminate the distortion. The presence of such distortion makes the cathode alignment more difficult than it should be because the distorted header will not properly fit a jig machined for a symmetrical piece. The mounting flanges must also be individually fitted to tubes having warped headers.

The bushings used were designed to be mechanically able to allow handling of the tube by holding the leads. This is not a recommended method of handling but we recognize that it will probably happen. The header used on the first tube was not successful in this aspect of its mechanical design. The bushings failed a crude torque test applied to the portion of the assembly which holds the lead wires; the vacuum seals did not fail. Consequently the leads are not fastened to the first tube in the manner planned or to be used in the future. Examination of the bushings showed that the amount of brazing filler material was not sufficient to provide the strength of joints desired.

F. <u>Tooling</u>

The precision of assembly of this design of 7890 depends upon the ability of the various jigs and fixtures used in brazing the component parts to hold the elements of the subassemblies in their proper places.

The principal problems encountered so far have been warpage of several of the jigs, probably caused by excessive reduction in the amount of metal in the jig, in order to reduce the mass and speed the heating of the parts in the brazing furnaces. The grid jigs have also proven to be larger in diameter than necessary. The metal used expands more than its published average expansion and allows the grids to be postioned off axis. This problem is readily overcome by the use of shims or by change in portions of the jigs; the warping problem may be more difficult.

The warping which produced the most trouble with parts assembled into the first tube is likely caused by the metal reduction mentioned above. There are indications, however, that warpage progresses with continued use. This is most apparent in portions of jigs such as base plates which are machines symmetrically. Because the jigs must maintain their dimensions with repeated heating, warpage at this early date is of some concern. The jigs are built of various stainless steels and Monel. If the warpage continues, complete redesign and different materials choices will be necessary.

The vacuum furnace has not been used for brazing since the failure of a water hose and the consequent filling of the system with water. Several hose materials have been investigated. Nylobrade, mentioned in the last report, is presently in the furnace. The vacuum obtained was improved when all commercial connectors were removed from the hose and copper tubing and the hose connections made with ordinary hose clamps. A small leak still exists in the furnace and the design of the system makes the location of the leak very difficult. The vacuum available is satisfactory for brazing operations but too long a time is required to attain the low pressure.

Modification was started to adapt the vacuum furnace to handle parts for the 7890 when in the early stages of the work it appeared that the hydrogen atmosphere retort furnace would not be ready in time for early use. However, the hydrogen furnace did become available and the use of the vacuum furnace is discontinued for this project.

The bell retort furnace has been satisfactory in its operation and we have determined that heat can be applied to an envelope assembly more rapidly than was initially considered safe. Therefore, the brazing cycle for envelope brazes can be shortened so

that it appears likely that three loads per eight hour day may be achieved using a single bell.

The exhaust manifold has not been converted to use compression fittings directly on a metallic pumping tubulation. We are using a Kovar-to-copper joint on the tubulation and sealing to a glass manifold. Because of the difficulty of putting a tube back on the pumps if it has been sealed off by a copper pinch, we have elected to keep the glass manifold during the early part of the development when there is a possibility that we may want to return a tube to the pumps to change the gas fill in the reservoir.

One senior test equipment has been modified to provide better cooling for the networks, load, and powerstats. Water cooling of the anode of the 7890 is provided and a set of good thermometers and a precision flow meter make measurement of anode dissipation possible. Another similar test set has been equipped with air cooling for the anode but no other modifications; tube aging only is performed in this gear.

II. Operation of First Sample Tube

The first 7890 was assembled, exhausted, and tested during the latter part of the report period. In general, Operation (2) tests were acceptable and Operation (1) tests could not be performed for the required length of time because of heating of the

grids. If the average and root-mean-square currents were reduced by lowering the repetition rate, the heating was tolerable and the tube continued to operate.

The tests were performed using a resistive voltage divider to control the potential on the gradient grid; 10^7 ohms were between the anode and gradient grid and between the gradient grid and cathode. This tube design has balanced interelectrode capacitances: A-G_2, 90 mmfd.; G_2-G_1, 87 mmfd. It is not necessary to add external capacitance for optimum operation. The use of a resistance divider duplicates field application and allows the tube to be turned on in any manner. It is not necessary to shock the tube into operation. The electrical leakage of the tube is so low that in the absence of the resistive divider stray electrons will put a negative charge on the gradient grid which must be overcome by a voltage transient during starting.

A. Test Data and Observations

The reservoir current at E_{res} of 3.5 volts was 9.98 amperes and the cathode heater current was 20.8 amperes under the specified test conditions. These are both just above the lower limits for the currents.

Operation (2) tests were performed with an inverse voltage spike of approximately 10 kilovolts, the forward voltage was 30

kilovolts and the peak current had an absolute value of 1150 amperes and an averaged peak value of 1085 amperes. Pulse width was 1.3 microseconds; repetition rate, 1500 pulses per second. The grid drive was 1100 volts although a higher voltage was required for the first several minutes of operation. Grid impedance was 75 ohms.

With a reservoir voltage of 4.7 volts, the tube operated one hour without incident. The temperature rise associated with the anode cooling water indicated that the anode dissipation reached 490 watts at the end of 0.1 hour operation and maintained this level for the remainder of the test. At the end of the test, the gradient grid ring was at 193°C. and the control grid ring measured in excess of 300°C., the maximum limit of the pyrometer then available.

The tube was found to have an indefinite lower reservoir voltage limit for this operation. Operation was technically within specification at a reservoir voltage of 4.1 volts; however, there appeared to be an instability associated with the rising portion of the current pulse other than that usually associated with low gas density. A contact pyrometer having a 0-600°C. range was obtained and the tube was operated for one hour with Eres at 4.1 volts. The anode dissipation was constant at 590 watts; the gradient grid showed a spot temperature of 160°C. and the control grid, 360°C.

There was little change in the operation of the tube as the reservoir voltage was increased to 4.3 volts. The tube has a safe range of 4.7 volts to 4.2 volts, inclusive, for this condition of operation.

The tube was operated for five hours at E_{res} of 4.5 volts. At the end of this time, the anode dissipation was determined from a 2^{o}F. difference in inlet and outlet water temperature at one gallon per minute flow. The anode dissipation of 300 watts and spot temperatures on the gradient grid of 185^{o}C. and control grid, 360^{o}C. indicated the tube was improving.

The Operation (1) tests were performed in a circuit that produced an inverse voltage of 7 kilovolts at 44 kilovolts forward voltage. The current wave shape was such that the peak current had an absolute value of 2900 amperes and an averaged peak value of 2580 amperes at 44 kilovolts forward voltage. The pulse width was 2.5 microseconds.

Operating at 360 pulses per second, the tube will go directly to 44 kilovolts on its anode at reservoir voltages ranging from 4.8 volts down to at least 4.4 volts. The true range was not determined because of an instability in the arc at this current at all reservoir voltages. The arc instability masked out the usual indication of low gas density which preceeds anode heating conditions in the tube.

At a reservoir voltage of 4.8 volts, and forward voltage of 44 kilovolts, the oscillations in the arc became objectionable in five to ten minutes; at 40 kilovolts anode voltage, 18 to 20 minutes is required for them to appear to the same amplitude on the current trace. At 40 kilovolts and 240 amperes peak current, the instability sometimes disappears and then returns. If the tube dissipation is reduced by operation at 44 kilovolts and 300 pulses per second, the tube will operate over a reservoir voltage range of 4.8 to 4.4 volts, inclusive.

The anode dissipation as determined by measurements of the coolant is less than 450 watts while the tube is operating at its specified test condition; therefore, the trouble must lie in the grid structures. The commutation time was approximately 0.1 microsecond which is several times the normal length of time usually required for the anode voltage to fall. The instability is oscillatory which suggests that the grid slots are acting as an inductance in the circuit. The oscillations cause losses in the grids that produce local heating and local loss of gas density necessary to remove the heat. It is likely that the grid dimensions are changing enough with the heating to cause loss of voltage hold-off ability.

The cathode appears to be more tightly baffled than is desired because approximately 1500 volts grid signal is required for

initial breakdown at E_{res} of 4.4 volts. As soon as the baffles heat from operation, the grid voltage may be reduced and the grid will continue to fire on the leading edge of its signal pulse. This also suggests that the baffles are so hot in operation that they do not remain emissive enough to provide the initial triggering current. Because of the baffle condition, no emission test was made of the first tube.

The tests normally performed during the Operation (1A) test at 360 pulses per second were performed at 300 pulses per second. With the anode at 44 kilovolts and the reservoir voltage at 4.5 volts, egy at 1500 volts, grid impedance at 75 ohms, the arc was oscillatory but the reduced repetition rate allowed the tube to continue operation. The anode dissipation during the test was 150 watts. The anode time delay at the end of two minutes operation was 0.22 microsecond and at the end of 60 minutes operation was 0.26 microsecond to give a drift of 0.04 microsecond.

The time jitter is well under the 0.005 microsecond limit; it appeared to be less than 0.002 microsecond.

B. Discussion of Test Results

The Operation (1) and (1A) tests and to a limited extent the Operation (2) tests showed that the tube was limited by an arc instability that is probably introduced by the grids. The in-

stability takes the form of an oscillation on the leading edge of the current pulse and the energy associated with the oscillation is dissipated in the grids. This operating condition, if continued, leads to loss of control.

The Operation (2) tests which produce more tube dissipation than Operation (1) conditions demonstrated the effectiveness of the external metal grid rings. In future testing, data concerning the ceramic envelope temperature will also be obtained.

The required grid voltage for initial breakdown indicates that the cathode baffling should be reduced. It is desirable to increase the cathode heater power and reduce the heat shielding in order to arrive at the same temperature presently obtained but in a shorter time.

The anode delay time data considered with the relatively long commutation time suggests that the grid overlap and grid openings are too small. The oscillation in the discharge also suggests that the grid openings are too small to carry the peak current without excessive losses.

The Operation (1) tests were not run long enough to be conclusive but the Operation (2) tests did show that the reservoir was not influenced to any considerable degree by the condition of tube operation. No pressure measurements were available but secondary effects such as loss of control after long time operation at the upper or lower ends of the range did not occur.

III. Changes to be Incorporated in Next Sample

The principal change to be made in the next sample will be to increase the area of the grid openings in an effort to reduce the instability and losses in the arc. The cathode baffling will be reduced to allow easier firing of the grid.

The reservoir mounting will be unchanged but the extra heater required to meet the minimum reservoir heater current specification will be placed in a metal enclosure and mounted in a more secure fashion than was used in the first tube.

Approximately 20 percent more power will be used for the cathode heater and one of the heat shields will be removed in order that the cathode heats faster; the heating time for the first tube appears marginal.

Efforts to prevent the control and gradient grids from being off the desired axis will be made even though new or reworked jigs will not be available for assembly of the second tube.

The gradient grid partition and cylinders will be suspended from a single copper spider as in the original design. The spider will be of heavier gauge material in order that the thermal conductivity will approach that obtained with the double spider arrangement.

CONCLUSIONS

The first tube has indicated that changes are necessary in the grid structures to reduce losses in the discharge and in the cathode structure to allow a lower grid voltage to be used to control the tube. In general, the performance of the first tube was within expectations and indicated that the basic design is sound. Modifications of grids and cathode are to be expected during the course of the project.

The troubles experienced with the jigs and fixtures used to position the components of the subassemblies during brazing can only be overcome by rework of the jigs or in some cases, a re-design. The jig and fixture problems should be eliminated during the construction of the first 10 tubes.

The principal structural trouble, the cracking of the anode cups during final brazing has been eliminated by addition of another part to the assembly. The construction problem next in importance is the support of the gradient grid and this will be further investigated in the next several tubes.

PROGRAM FOR NEXT INTERVAL

1. Construct a sample tube containing changes detailed on page 23.
2. If the above sample is successful, construct another similar tube and order parts for preproduction tubes.
3. If the above sample is not successful, construct another incorporating changes then desired.
4. Deliver Engineering Samples to Signal Corps.
5. Assuming satisfactory progress on Engineering Samples, start tubes for preproduction tests.

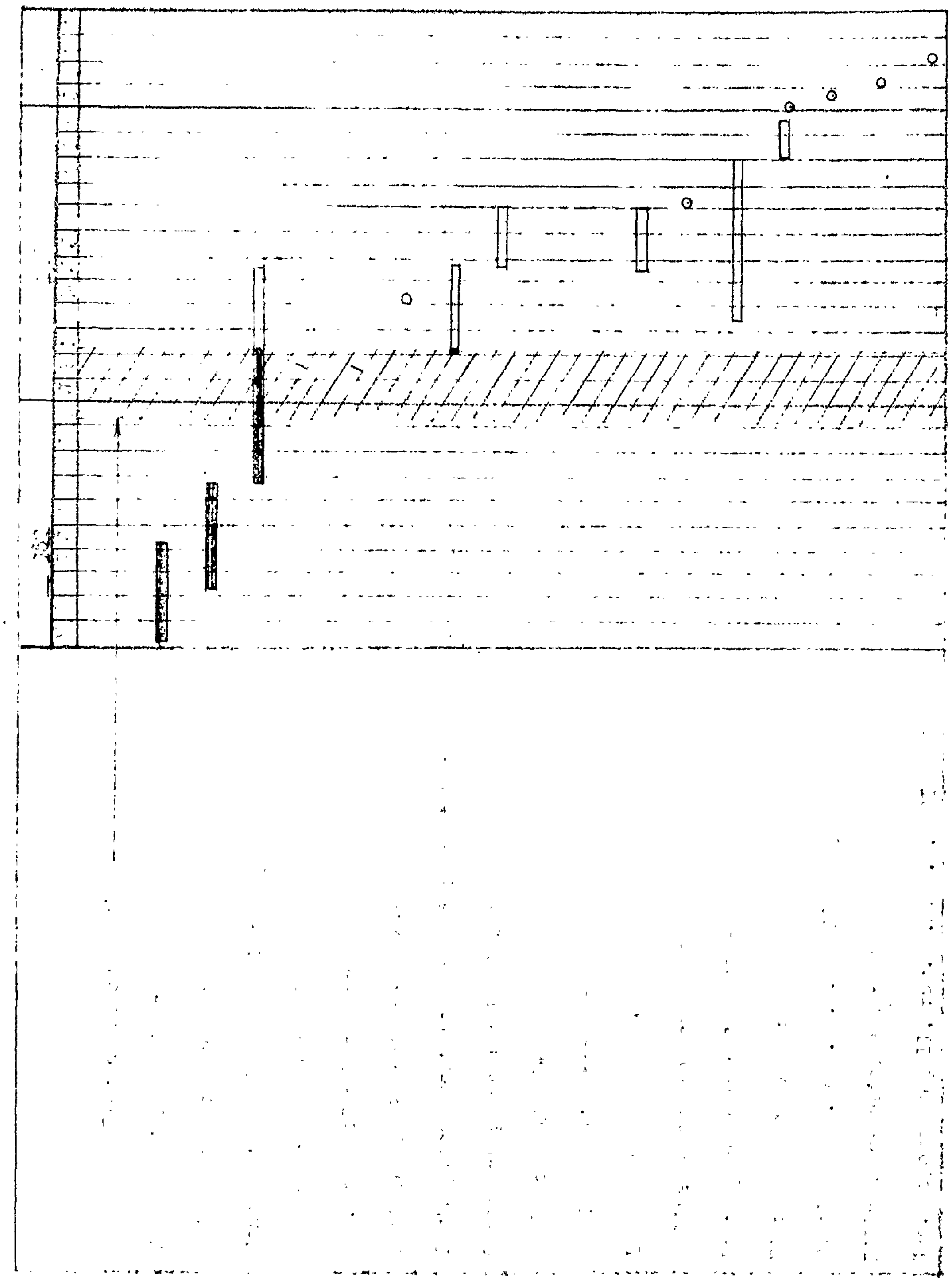
PUBLICATIONS AND REPORTS

NONE

PLANNING AND PROGRESS CHART

The Planning and Progress Chart on the following page shows actual progress as compared with planned operations.

It was hoped that a greater number of engineering samples would be made during the present report period but the cracked anode flanges set this part of the operation back approximately two months.



IDENTIFICATION OF TECHNICIANS

		Hours
B. F. Steiger	Director of Engineering	---
C. L. Shackelford	Project Engineer	233
A. Autullo	Electrical Technician	60
F. Roth	Mounting Technician	68
M. Liebruder	Vacuum Technician	57

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